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# A Study Analysis and Performance of High Pressure Boilers With its Accessories

J. Suresh babu[1],R.Latha[2] ,B.Praveen[3],V.Anil kumar[4],R Rama kumar[5],s.peerulla[6]

[1] *Assistant Professor in MED, K.S.R.M College of engineering, AP, India*
[2 3 4 5 6] *Student, mechanical department, K.S.R.M College of engineering, AP, India*

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Abstract - *Power constitutes the basic and essential input for rapid economic development. In this modern scenario energy place a vital role both in industrial development, which in turn leads to the prosperity generation facilities developed in AP to meet growing demand for power. By using accssories in the boiler. The efficiency of the plant increases. For example the accessories like Economizer increases the feed water temperature while super heater increases the temperature of the steam produced in the boiler. The air pre heater increases the inlet air temperature, which enters into the furnace. The main objective of present project work is to analyze the efficiency of economizer, super heater& air pre heater by varying the various parameters in boiler section.*

*Key Words: RTPP,BOILERS,ACCESSORIES ETC*

## 1. INTRODUCTION

Rayalseema Thermal Power Plant is one of the major power generation facilities, developed in Andhra Pradesh, to meet the growing demand for power, the project envisaged the installation of 5*210mw coal based thermal generation unit.

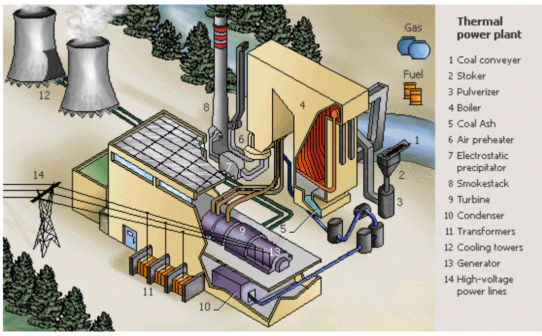



***Fig-1 Steam power plant***

### 1.1- ESSENTIAL INPUTS TO THE PLANT

1.1.1- coal:

The coal Is used in RTPP is sub- bituminous .It is similar to lignite it contains 50% less moisture than lignite .It also contains less than lignite but it has caking power & also used either I the form of pulverized state

1.1.2-Furnace oil and diesel oils

LDO (light diesel oil ) used for firing ,HFO(heavy furnace oil)used for flame support and stabilization.

1.1.3-Water

The water requirements of the project are met from Mylavaram Reservoir across Penna River situated at a distance 23 km

### 1.2-plant operations

1.2.1-Coal plant operation

The coal is crushed into a size of 20mm.If any problem occurs in one path, the process is diverted to another path from the motor control cabin itself.

1.2.2-Fuel oil pump house :

1. Heavy furnace oil 2. Light diesel oil.

1.2.3-Feeders

The principle function of a coal feeder is to control the flow of coal to the pulverizes to meet the steam demand.

1. Volume feeder
2. Gravimetric feeder

1.2.4-Mills

It grinds down pieces of coal into fine powder ,which is to be fed to the boiler furnace.

1.2.5 fans

Fans are provided trough out the steam electric generating unit to supply air on to exhaust flue gas.

1.2.6-Boiler

1.2.6.1-Boiler drum

The drum encloses the steam water interfaces in a boiler and provides a convenient for addition of chemical and removal of dissolved solid s from the water steam system.

1.2.6.2-Soot blowers

Soot blower are used for removal of ash deposits from the fireside of heat transfer surface.

1.2.6.3-Valves

The primary function if control valve is to regulate the steam flow to the turbine and thus control the output power of steam turbine generator.

## 2. BASIC STEAM POWER CYCLES

2.1-CARNOT CYCLE

Fig 2.1 shows a Carnot cycle on T-s diagram and p-v diagrams .It contains of (a)Two constant pressure operations(4-1)and(2-3) & (b).Two frictionless adiabatic(1-2)and(3-4).

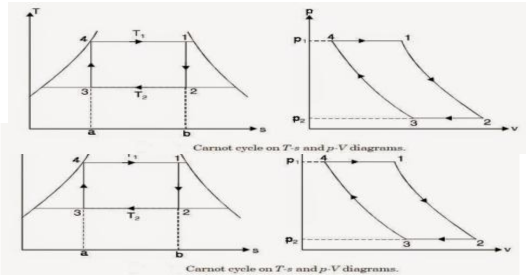



Fig2- Carnot cycle on T-s and P-v diagrams

2.2-RANKINE CYCLE: Rankine cycle is the theoretical cycle on which the steam turbine (or engine) works.

THE RANKINE CYCLE EFFICIENCY CAN BE IMPROVED BY:-

~Increasing the average temperature at which heat is supplied.

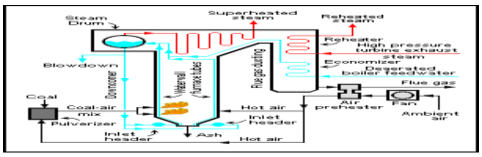
~Decreasing or reducing the temperature the conditions of steam at which heat rejected.

This can be achieved by making suitable changes in generation or condensation as discussed below.

1. Increasing boiler pressure.
2. Super heating.
3. Reducing condenser pressure.

## 3.INTRODUCTION TO STEAM GENERATORS

Steam generator popularly known as boiler made of high quality steel in which steam is generated from water by application of heat.




3.1-STEAM GENERATOR

Fig- 3 Formation of steam in a boiler

The word "saturated" in this sentence, however, indicates that the steam is saturated with heat and no moisture is present .It is often called "dry saturated steam"

Modern water tube boilers can operate at pressures in excess and generate more than 9million lb of steam per hour. Because combustion temperatures may exceed 3000°K, The water flow is controlled by natural or forced circulation .By super heaters modern boilers can achieve almost 90% efficiency.

3.2 BOILER MOUNTINGS AND ACCESSORIES:

Mountings

These are different fittings and devices that are necessary for the operation and safety or boiler.

1. Safety valve
2. Water level indicator
3. Pressure gauge
4. Feed check valve
5. Blow off cock
6. Fusible plug
7. Steam stop valve
8. Man hole
9. Mud holes or sight holes

ACCESSORIES:

These are auxiliary parts required from steam boiler for their proper operation and for increase the efficiency.

- Feed pumps
- Economizer
- Air preheater
- Super heater
- Steam separator.

3.3-PERFORMANCE OF BOILER

Evaporative Capacity:

Evaporative capacity of boiler is the amount of steam generated per hour. It is represented in following units.

Equivalent Evaporation:

The term equivalent evaporation is defined as the amount of water evaporated from water at 100°c to steam at 100°c.

Factor of Evaporation:

The ratio of heat received by 1kg of water under working conditions to that received by 1 kg of water evaporated from and at 100°c.

Boiler Efficiency:

The ratio of heat actually utilized in generation of steam to that heat supplied by the fuel in the same period.

## 4. ACCESSORIES

4.1-ECONOMISER

"An economizer is a device which extracts a part if heat from the flue gases and used for heating the feed water

4.1.1. IMPORTANCE

Use of economizer increases the boiler efficiency, and then the overall efficiency of the plant increases.

4.1.2 DESCRIPTION OF ECONOMISER

The economizer is a feed water heater deriving heat from the flue gases discharged from the boiler. The greatest item in a boiler is the heat carried away by the flue of the chimney or stack .some of heat being carried away by the flue gases may be recovered and sent back into the boiler. In the economizer if the path of feed water placed in the path of flue gases in between the exit from the boiler and enters the chimney, the heat from the flue gas is transferred to the feed water. The economizers the fuel and steam rate is increased. It has been found that a rise in temperature of feed water by 6c improves the boiler efficiency by 1%.

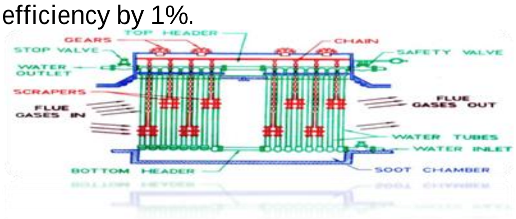



Fig -4 Economizer

4.2 ECONOMISER IN RTPP:

TYPE: The economizer used in RTPP is grilled bare tubes horizontally spaced economizer.
LOCATION: The economizer is located at the top if the boiler at the height of 56.025 to 62.23m from the ground floor.
Economizers are generally placed between the last super heater and re heater and air pre heater.

4.3 WORKING OF ECONOMISER

The economizer consists of two sections. The lower section is known as non-steaming economizer and the upper part is known as steaming economizer. The economizer is placed above the re heater. The hanger plates are used to support economizer tubes.

4.4 SPECIFICATIONS OF ECONOMISER IN RTPP
TYPE

Grilled bare tube horizontal speed economizer
Total heat surface area : 7911m2
Number of blocks :2
Volume of economizer : 25m3

## 5. SUPER HEATER

5.1-FUNCTIONS

"The function of the super heater is to increase the temperature of steam above the saturation point. The super heater is very important accessory of boiler. Another function of a super heater is to remove the lost traces of moisture (1-2%) from the steam coming out boiler."

5.2 Advantages:

- Due to installation of super heater the thermal efficiency of plant increase.
- Losses due to condensation in the cylinders and steam pipes are reduced.
- Heat of the flue gas is maximally utilized.
- Erosion of blade is reduced.
- Steam consumption rate of engine or turbine is reduced.

5.3 DESCRIPTION OF SUPER HEATER

The steam produced in boiler in nearly saturated. This as such should not be used in the turbine because the dryness fraction of steam leaving boiler will be low. This results in the presence of moisture, which causes corrosion of turbine blades .To rise the temperature of steam ,super heaters used. super heater supplies steam at constant temperature at different loads. The use of super heated steam increases efficiency.

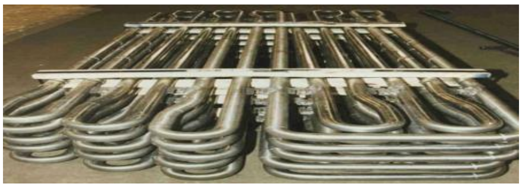


Fig -5 Super heater

5.4CLASSIFICATIONS

SUPER HEATERS ARE CLASSIFIED AS:
Convective super heater: the heat of combustion gases are transferred to the surface of tubes by convection.
Radiant super heater: The heat of combustion gases are transferred to the surface of tubes by radiation

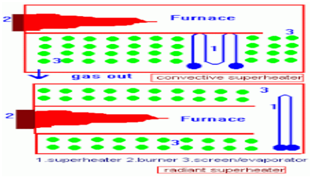



Fig-6 Types of super heater

5.5 SUPER HEATER IN RTPP
TYPE
The super heater used in RTPP is convective type, horizontal super heater
Regions in super heater:
The hanger platen is located directly above the furnace
LTSH is arranged in counter flow and is located between the low temperature re heater and super heater
ITSH is arranged for parallel flow and is located between the high temperature re heater and hanger platen.
HTSH is arranged for counter flow and is located between the low temperature super heater and high temperature re heater.

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### 5.6 DESIGN CONSIDERATIONS

The steam temperature is specified
The range of boiler loaded over which steam temperature is to be controlled
The super heater surface require to give this steam temperature
The gas temperature zone in which the surface is to be located
The type of steel, alloys are other material best suited for the surface and supports.
The rate of steam flow through the tubes, which is limited by the permissible steam pressure drop, but in turn ,exerts a dominant control over the tube metal temperature.

### 5.7 SPECIFICATIONS OF SUPER HEATER IN RTPP

Heating surface area:
LTSH=3055m2, ITSH =1435m2, HTSH =2715m2

## 6 AIR PRE HEATER

### 6.1 INTRODUCTION

Air heater is a heat transfer surface in which air temperature is raised by transferring heat from flue gas. Hot air is necessary for rapid and efficient combustion in the furnace and also for also for drying coal in the milling plant, so on essential boiler accessory, which serves this purpose.

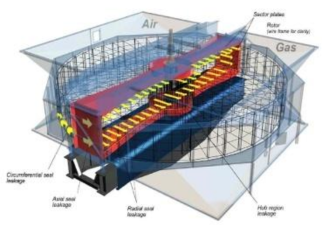


Fig -7 Air pre heater

### 6.2Air Pre heater In RTPP:

As the name implies, the tri-sector re heater design has three sectors. one for flue gas one for primary air(Used for drying and transporting of coal through mill to the burner).As the rotor slowly revolves the mass of the elements alternatively through the air and gas passages, heat is absorbed by the element surfaces passing through the hot gas stream, then as the same surface are carried through the air stream, They release the stored up heat thus increase the temperature of the incoming combustion are process air.

### 6.3APPLICATIONS

1. Electric Power generating plants.
2 .Fluidized Bed and marine boilers
3. Package and large industrial boilers.
4 .Hydrocarbon and chemical processes.
5. Waste incinerators and drying systems.
6. Flue gas and other reheating systems.
7. Heat transfer surfaces.

## 7. RESULTS AND CALCULATIONS

### 7.1-BOILER:

DATA COLLECTION:
Mass flow rate of coal ($M_c$) =150 TPH
Calorific value of coal (CV) =3686 K cal/kg
Mass flow rate of feed water ($M_w$) = 653 TPH
Specific enthalpy of steam ($H_s$) = 2801 KJ/Kg

FORMULAE:

Heat input $=(massofcoal * cvofcoal)$

$$=\frac{M_c*cv*1000}{3600}$$

Heat output = heat raised in steam

$$=\frac{M_s*1000*2801}{3600}$$

Efficiency (η) $=\frac{Heatoutput}{Heatinput}*100$

Results and calculations:

a. Heat input $(H_i)$ $=\frac{665*15422.22*1000}{3600}$

$= 642591.66$ KW

b. Heat output $(H_o)$ $=\frac{653*2801*1000}{3600}$

$= 508070.27$ KW

c. Efficiency ($\eta$) = $\frac{508070.27}{642591.66}*100$ =79.06%

### 7.2-Economizer

FORMULAE:

(a). Efficiency of economizer $(\eta_{eco})=\frac{M_w*C_{pw}*(T_2-T_1)}{M_f*C_{pf}*(T_{f1}-T_a)}*100$

(b).Heat transfer rate of economizer

$$(Q_{eco})=\frac{M_f*C_{pf}*(T_{f2}-T_a)*1000}{3600}$$

(c). Percentage of heat utilization in economizer

$$PHUE=\frac{M_w*C_{pw}*(T_2-T_1)}{M_c*CV}*100$$

(d). Effectiveness of economizer:

Heat gained by system$(Q_s)=\frac{M_w*C_{pw}*(T_2-T_1)*1000}{3600}$

Heat losses by flue gases$(Q_h)=\frac{M_f*C_{pf}*(T_{f2}-T_{f1})*1000}{3600}$

Average $Q=\frac{Q_c+Q_h}{2}$

Area of outlet ,$A_o=n*\pi*D_o*L$

(e).External overall heat transfer coefficient,

$$(U_o)=\frac{Q}{A_o*LMTD}$$

Where,
Logarithmic mean temperature difference

$$LMTD=\frac{(\theta_i-\theta_o)}{\ln\left(\frac{\theta_i}{\theta_o}\right)}$$

$\theta_i = inlet\ temparature\ differene\ (T_{f1}-T_1)$

$\theta_o = Outlet\ temparature\ difference\ (T_{f2}-T_2)$

 

GRAPHS FOR ECONOMIZER

| Mass flow rate of coal $(kg/sec)$ | Mass of feed water $(kg\ /s$ | Effectiveness by NTU |
|---|---|---|
| 39. | 186.5 | 0.7 |
| 36.09 | 198.13 | 0.66 |
| 36.64 | 200.00 | 0.683 |
| 40.509 | 198.05 | 0.66 |
| 35.185 | 196.22 | 0.747 |

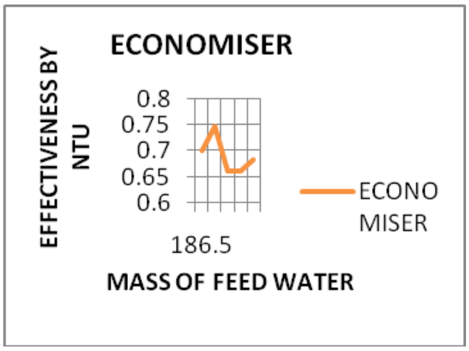


Chart -1: Effectiveness of economizer

As the mass of feed water increases the effectiveness of economizer decreases.

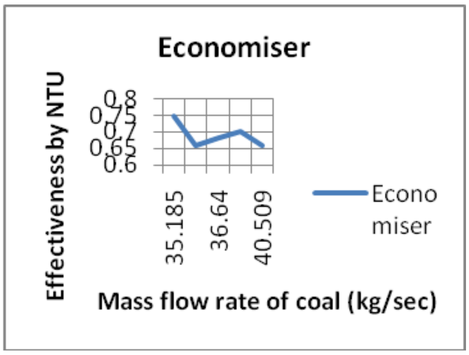


Chart-2: Effectiveness of economizer

If the economizer tubes are made of alloy steel ,the thermal properties can be improved

Results of economizer:-
1. Efficiency of economizer $\eta_{eco} = 53\%$
2. Heat transfer rate of economizer $Q_{eco} = 84408.26\ Kw$
3. Percentage of heat utilized in economizer PHUE =8.914%
4. Heat gained by water $(Q_w) = 49373.14\ Kw$
5. Heat lost by flue gases $(Q_f) = 19773.22\ Kw$
6. Effectiveness of economizer $(\varepsilon) = 0.449$
7. Effectiveness of economizer by NTU method $(NTU\ \varepsilon) = 0.70$

## Super heaters:

FORMULAE :

- $\eta_{sh} = \frac{M_s * C_{ps} * (T_{s2} - T_{s1})}{M_f * C_{pf} * (T_{f1} - T_{f2})} * 100$
- $Q_{sh} = \frac{M_f * C_{pf} * (T_{f1} - T_{f2}) * 1000}{3600}$
- Percent heat utilization (PHUE) $= \frac{M_s * (H_2 - H_1)}{M_c * cv} * 100$
- Heat gained by steam $Q_c = M_s * C_{ps} * (T_{s2} - T_{s1}) * \frac{1000}{3600}$
- Heat losses by flue gases $Q_h = M_f * C_{pf} * (T_{f1} - T_{f2}) * \frac{1000}{3600}$
- Average , $Q = \frac{Q_c + Q_h}{2}$
- Area of outlet , $A_o = n * \pi * D_o * L$
- External overall heat transfer coefficient, $(U_o) = \frac{Q}{A_o * LMTD}$

Where ,
Logarithmic mean temperature difference,

$$LMTD = \frac{(\theta_i - \theta_o)}{\ln\left(\frac{\theta_i}{\theta_o}\right)}$$

$\theta_i = inlet\ tempaDature\ differene\ (T_{f1} - T_1)$
$\theta_o = Outlet\ temparature\ difference\ (T_{f2} - T_2)$

Heat capacity of hot fluid $C_h = M_w * C_{pf} * \frac{1000}{3600}$

Heat capacity of cold fluid $C_c = M_w * C_{pw} * \frac{1000}{3600}$

If $C_h < C_c$ then effectiveness, $\varepsilon = \frac{T_{f1} - T_{f2}}{T_{f1} - T_1}$

Otherwise, $\mathcal{E} = \frac{(T_2-T_1)}{(T_{f1}-T_1)}$

BY NTU Method :

If $C_h < C_c$ $then$ $C_{min} = C_h$ $and$ $C_{max} = C_c$

Otherwise $C_{min} = C_c$ $and$ $C_{max} = C_h$

Number of transfer units

NTU $= \frac{U_o * A_o}{C_{min}}$

Ratio of hear capacity, $R = \frac{C_{min}}{C_{max}}$

NTU $\mathcal{E} = \frac{(1-\exp(-NTU*(1-R)))}{(1-R*(\exp(-NTU*(1-R)))}$

SUPER HEAER GRAPHS

| Mass flow rate of steam (kg/sec) | Mass of flow ate of steam (kg/sec) | Effectiveness by NTU LTSH | ITSH | HTSH |
|---|---|---|---|---|
| 204.31 | 186.5 | 0.472 | 0.206 | 0.312 |
| 225.0 | 198.135 | 0.439 | 0.259 | 0.3 |
| 224.72 | 200.0 | 0.50 | 0.30 | 0.34 |
| 206.94 | 204.31 | 0.437 | 0.206 | 0.34 |
| 204.31 | 206.94 | 0.72 | 0.28 | 0.33 |

By observing the above graph the effectiveness of three types of super heaters increases by increasing mass flow rate of steam.

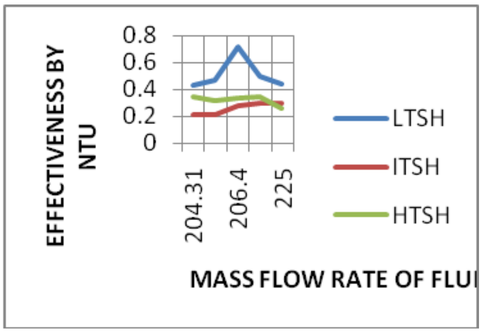


**Chart-3** Effectiveness of super heat

By the above graphs we can conclude that the effectiveness for ITSH is less as compared with LTSH, HTSH .This can be improved by using aluminum alloy steel , which has higher thermal properties.

## AIR PREHEATER:

Calculation:

$T_{gnl}$ =[AL*$C_{pa}$($T_{gl}$-$T_{ae}$)/(100*$C_{pg}$)]+$T_{gl}$

[22.5*1.023(175-40)/(100*1.109)]+175=203°C

Air heater gas side efficiency:

Gas side efficiency (GSE)=[($T_{ge}$-$T_{ngnl}$)/($T_{ge}$-$T_{ae}$)]*100

= [(331-203)/(331-40)]*100=43.92°C

Air side efficiency (SA&PA):

Ratio of air temperature gain across the air heater corrected from no leakage to the temperature head

Air side efficiency =[($T_{al}$-$T_{ae)}$/($T_{ge}$-$T_{ae}$)]*100

Collected data:

$T_{ae}$- Temperature of air entering air heater=40°C

$T_{al}$- temperature of air leaving air heater =295°C

$T_{ge}$- Temperature of gas entering air heater=331°C

Calculation :

Air side efficiency =[($T_{al}$-$T_{ae)}$/($T_{ge}$-$T_{ae}$)]*100

=[(295-40)/(331-40)]*100=87.62%

X-ratio ($X_r$)=gas side efficiency /air side efficiency

$X_r$=43.92/87.62=0.5

Gas leaving temperature without leakage

$T_{gl}$=$T_{ge}$-$X_r$($T_{al}$-$T_{ae}$)

=331-0.5(295-40)=203.5°C

Pre heater air side efficiency:

Air side efficiency = [($T_{ge}$-$T_{gl}$)/($_{ge}$-$T_{ae}$)]*100

=[(331-203.5)/(331-40)]*100=43.8%

From this comparison air leakages in rothemuhle are higher than Ljungstrom and air side, gas side efficiencies are less in Rothe mule.

AIRPREHEATER:

| % of oxygen entering into the Air pre heater | Air leakage | Gas side efficiency |
|---|---|---|
| 3.86 | 3.97 | 60.7 |
| 3.89 | 4.62 | 60.8 |

| | | |
|---|---|---|
| 3.75 | 4.29 | 59.75 |
| 3.88 | 4.61 | 62.09 |
| 3.92 | 5.04 | 64.58 |

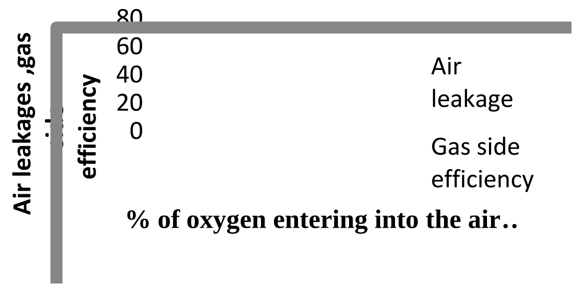


Chart-4 Air leakage of air pre heater

As the percentage of oxygen entering increases the air leakage and gas side efficiency increases.

## 8. CONCLUSIONS:

1.By using the Economizer

By installing the economizer in the plant in the plant, the plant efficiency can increased by 10 %.

2. By using super heater

By implementing the super heater the efficiency can be increased by (25 - 30)%, ( 8-10) % in each stage of super heater

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[5] Thermal engineering-M.L. Mathur &Mehtal/join bros

## BIOGRAPHIES

J. Suresh Babu is currently working as Assistant Professor in MED, K.S.R.M. College of Engineering (Autonomous), Kadapa, He received the B. Tech (Mechanical Engg.) from S.V. University, Tirupati in 2006, M. Tech degree from JNTUH, Hyderabad in 2010 His areas of interest include, IC Engines, Thermal, Heat Transfer, Design and Manufacturing

R. Latha is presently studying 4th year mechanical engineering in K.S.R.M College of engineering

B. Praveen kumar reddy is presently studying 4th year mechanical engineering in K.S.R.M College of engineering

V. Anil kumar is presently studying 4th year mechanical engineering in K.S.R.M College of engineering

P. Ram kumar is presently studying 4th year mechanical engineering in K.S.R.M College of engineering

S. Peerulla is presently studying 4th year mechanical engineering in K.S.R.M College of engineering